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NARRATIVE REVIEW

Airway management in critically ill patients with obesity

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Abstract: Obesity is a global health challenge. An increasing number of patients with obesity are admitted to an intensive care unit. Airway management in these patients represents a unique challenge due to significant anatomical and physiological alterations. Increased adipose tissue in the face, cheeks, pharynx, hypopharynx, and neck narrows the upper airway, renders soft tissues more collapsible, and complicates airway management. In addition, the functional residual capacity is reduced, resulting in markedly shortened safe apnea time, contributing to severe hypoxemia during intubation. Non-invasive ventilation is effective in mitigating this risk and should be applied from pre-induction to laryngoscopy. Peri-intubation physiological optimization should include assessment of preload and cardiac contractility, with careful consideration of right ventricular strain. The transition from negative to positive intrathoracic pressure should be closely monitored, with cautious titration of positive end-expiratory pressure. Recognition of these anatomical and physiological challenges may prompt clinicians to consider awake intubation in selected patients. When rapid sequence induction is performed, both ketamine and etomidate are appropriate options; the choice between them should be guided by the clinical context, patient characteristics, local practice patterns and availability. Videolaryngoscopy increases the incidence of successful intubation on the first attempt and should be adopted routinely in the population with obesity. Several questions remain unanswered, including the safety and efficacy of pre-emptive vasopressor use to prevent post-intubation cardiovascular collapse and the optimal dosing of hypnotic agents to achieve ideal intubation conditions, while minimizing adverse events.

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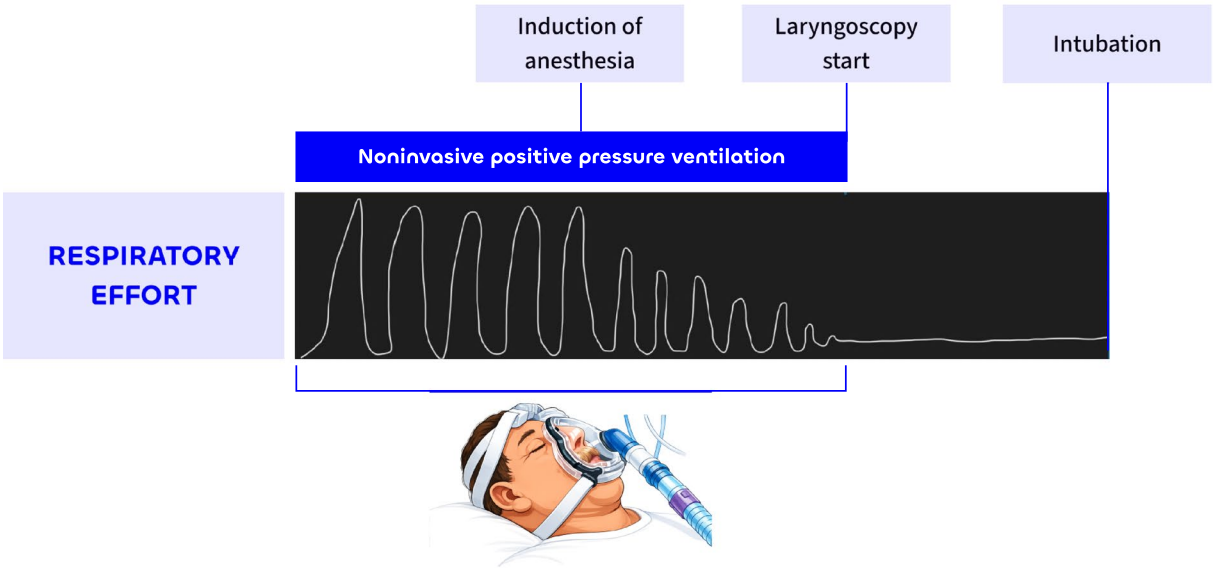
Visual abstract:

AIRWAY MANAGEMENT IN CRITICALLY ILL PATIENTS WITH OBESITY



Clinical relevance

Airway management in critically ill patients with obesity is not just a "difficult airway" issue — it is a race against physiology.

Findings

This review explains how reduced FRC, rapid desaturation, anatomical challenges, and peri-intubation hemodynamic vulnerability converge to make intubation uniquely high-risk in this population.

Practical strategies to reduce complications

- NIV-based preoxygenation
- Positive-pressure ventilation before laryngoscopy
- Optimized positioning
- Routine videolaryngoscopy
- Careful induction drug selection
- Early hemodynamic planning

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Introduction: the growing challenge of obesity in critical care

Obesity represents a growing public health challenge, with 43% of the adult population classified as overweight and 16% obese according to the 2022 World Health Organization report [1]. The prevalence of obesity is projected to increase both in adults and children, with an estimated 18% of adults affected by 2030. Between 25% and 40% of ICU admissions involve patients with obesity [2, 3]. Individuals with obesity are more commonly affected by arterial hypertension, diabetes, and obstructive sleep apnea syndrome (OSAS), and they more commonly have at least one of the recognized anatomical predictors of difficult airway management, such as short neck, reduced mouth opening, large tongue and higher Mallampati scores [4]. These anatomical features, which increase the complexity of airway management (i.e. anatomically difficult airways), coexist with physiological alterations (i.e. physiologically difficult airways), making critically ill patients with obesity a distinct population, at high risk of peri-intubation adverse events. Critical illness represents a unique challenge in airway management [5]. Critically ill patients with obesity then constitute a population at particularly high risk for airway-related morbidity and mortality [2, 5, 6].

The aim of this review is to provide updated evidence on airway management in critically ill patients with obesity, from pathophysiological alterations to evidence-based strategies for mitigating peri-intubation adverse events. We conducted a search of MEDLINE for randomized and observational studies, as well as meta-analyses, providing relevant data on the pathophysiology and bedside airway management of critically ill patients with obesity. The search strategy combined Medical Subject Headings (MeSH) with free-text keywords, including "intubation," "critically ill patients," and "obesity." We included studies published in English between 2000 and 2026 that involved adult patients. The selected search time frame was defined to optimize sensitivity while ensuring the inclusion of studies representative of contemporary airway management practices in critically ill patients with obesity. The reference lists of the retrieved articles were screened to identify additional relevant studies. Each author contributed to a specific section based on their clinical and research expertise in the respective topic.

Take-home messages

Critically ill patients with obesity are at increased risk of complications during intubation, and hypoxemia is the most common adverse event in this population. Positive pressure preoxygenation improves functional residual capacity and mitigates the risk of post-induction hypoxemia, while videolaryngoscopy may contribute to risk reduction by increasing the rate of first pass success.

Anatomical and physiological alterations in patients with obesity impacting airway management

Obesity is a complex condition affecting all organ systems [7]. The major modifications in anatomy and physiology influencing airway management are observed in abdominal (android fat distribution) obesity. Obesity affects the anatomy of the head, neck, and upper airway, potentially making laryngoscopy and tracheal intubation more difficult [8]. Obesity (i) increases the amount of adipose tissue in the face, cheeks, pharynx, hypopharynx, and neck, narrowing the airway space and making soft tissues more collapsible; (ii) increases the circumference of the neck and makes displacement of the mandible more difficult; (iii) increases the fat pads on the back and shoulders, restricting extension of the neck and making alignment of the oral, pharyngeal, and laryngeal axes to obtain a view of the vocal cords more challenging. These features are commonly observed in patients with increased neck circumference and OSAS, and are associated with upper airway compression and difficult mask ventilation [6]. Although findings have been inconsistent, studies have suggested that patients with obesity are less likely to experience successful intubation on the first attempt, compared with those without obesity [8, 9] Thick pre-tracheal soft tissue, short neck and difficult landmark identification represent a challenge also for tracheostomy performance, and can increase the risk of tube displacement.

Obesity has a major impact on respiratory physiology, which can be summarized as increased respiratory workload and impaired gas exchange. The increased work of breathing is driven by the higher tissue weight of the abdomen and chest wall, along with a higher airway resistance due to smaller airway dimensions [6]. In parallel, obesity also increases oxygen consumption due to increased metabolic demand.

The major driver of impaired gas exchange is reduced lung volume due to cranial displacement of the diaphragm caused by increased tissue mass in the abdomen and in the chest wall. The decrease in the resting volume at expiration, the functional residual capacity (FRC), is a key component of the respiratory pathophysiology of obesity [10].

In healthy subjects, FRC is approximately 30–35 mL/kg of predicted body weight in the sitting position or 2500 mL for a 70-kg adult male [10]. Increasing adiposity is associated with a progressive reduction in FRC, estimated at 5–15% for every 5 kg/m^2 increment in body mass index (BMI) [11]. The reduction of FRC is responsible for airway closure and atelectasis formation, which more profoundly affects the dorsal lung regions [6]. The FRC represents the oxygen store during apnea, so its reduction is responsible for a reduced safe apnea time (i.e. the time needed for the saturated hemoglobin to decrease from 100 to 90% which, given the hemoglobin dissociation curve shape, represents a critical level with subsequent steep desaturation) [10]. During apnea, in a paralyzed healthy patient, the total body oxygen consumption ($\dot{V}O_2$) is approximately constant, and about 230 mL/min for a healthy patient at rest and higher in critical illness. In patients with morbid obesity, resting $\dot{V}O_2$ can reach 300–400 mL/min. The reduction of FRC (the *oxygen store*), combined with a higher oxygen consumption, explains the rapid desaturation typically observed when apnea is induced to facilitate tracheal intubation in patients with obesity.

Obesity also influences cardiovascular physiology [12]. The left ventricle frequently shows hypertrophy leading to higher filling pressures to maintain cardiac output, which is increased due to the higher metabolic demand. Moreover, right ventricular (RV) vulnerability is a major risk in patients with obesity. RV strain is frequently observed as the consequence of obstructive sleep apnea or obesity hypoventilation syndrome, reduced lung volumes and chronic hypoxic vasoconstriction, elevated intrathoracic and pleural pressures [12]. Finally, increased inflammation and endothelial dysfunction may promote cardiovascular remodeling. These alterations may significantly influence hemodynamics at induction, particularly during the transition from negative intrathoracic pressure generated by spontaneous breathing to positive-pressure ventilation, and through their interplay with peri-intubation hypoxemia.

Positioning matters

Obesity affects patients' physiology and anatomy in ways that may make the choice of patient position during preoxygenation, facemask ventilation, laryngoscopy, and intubation uniquely important. Patient positioning should be optimized during these phases to reduce the incidence of complications.

Positioning during preoxygenation

Obesity decreases patients' FRC, impairs the lung's ventilation-perfusion matching, and increases the body's consumption of oxygen. As a result, severe hypoxemia during intubation is more common in patients with obesity than in those without. The position of the patient may affect the effectiveness of preoxygenation. Compared with a position in which the patient's torso is horizontal (supine position), receiving preoxygenation in a position in which the torso is angled upward (ramped position or reverse Trendelenburg position) or vertical (upright position) increases FRC, improves ventilation-perfusion matching, and decreases atelectasis by displacing the abdominal contents away from the diaphragm. Multiple randomized trials among patients with obesity undergoing tracheal intubation for elective surgery in the operating room have found that preoxygenation in the ramped or upright position decreases the risk of hypoxemia, as compared with tracheal intubation in the supine position [13, 14]. No randomized trials have examined patient position during preoxygenation before tracheal intubation in the ED or ICU. Based on the available evidence, critically ill patients with obesity undergoing tracheal intubation should receive preoxygenation with non-invasive ventilation (unless contraindicated) and could potentially benefit from preoxygenation in a ramped, reverse Trendelenburg, or upright position, rather than in a supine position—though further evidence on positioning of critically ill adults during preoxygenation is needed.

Positioning during laryngoscopy and intubation

For patients with obesity, laryngoscopy and intubation with the patient in the ramped or head-elevated laryngoscopy position (HELP) has been hypothesized to facilitate alignment of the oral, pharyngeal, and laryngeal axes, visualization of the vocal cords, and intubation of the trachea (addressing the anatomical difficulty associated with intubation in patients with obesity). Randomized trials among patients with obesity undergoing tracheal intubation for elective surgery in the operating room have shown mixed results—with some reporting that ramped position facilitated intubation and some reporting no difference [15–17]. One randomized trial compared ramped position versus sniffing position among 260 critically ill adults undergoing tracheal intubation in 4 ICUs [18]. Overall, use of ramped position appeared to increase the incidence of poor grades of glottic view, decrease the incidence of successful intubation on the first attempt, and increase the incidence of difficult intubation—without affecting the incidence of hypoxemia during intubation. Results were similar in the subgroup of patients with obesity. The increased difficulty of intubation may be related to difficulty ensuring adequate flexion of the

neck and extension of the head in the ramped position. Based on the available evidence, a reasonable approach for patients with obesity undergoing emergency tracheal intubation would be to (i) preoxygenate in the ramped or upright position and (ii) transition to a sniffing position in which the external auditory meatus is aligned with the sternal notch for laryngoscopy and tracheal intubation.

Oxygenation and ventilation during intubation of the critically ill patient with obesity

Hypoxemia is one of the most common complications of emergency tracheal intubation, occurring in up to 25% of all intubations in the ED and ICU, and is associated with cardiac arrest and death [19]. The risk of hypoxemia during intubation may be reduced by the provision of supplemental oxygen and positive pressure at three distinct phases: (1) before induction of anesthesia (preoxygenation); (2) between induction of anesthesia and initiation of laryngoscopy; and (3) during laryngoscopy and intubation (apneic oxygenation).

Preoxygenation

Preoxygenation is the administration of supplemental oxygen before induction of anesthesia and can include supplemental oxygen and positive pressure. Supplemental oxygen increases the content of oxygen in the lungs at induction while positive pressure increases the lung volume and PaO_2 at induction. Historically, most critically ill patients have been preoxygenated with an oxygen mask without positive pressure [20–22]. Three recent trials have found that the addition of positive pressure provided during preoxygenation via non-invasive ventilation reduced hypoxemia among critically ill adults undergoing intubation in the ED and ICU [23–25]. The largest of these, the 1.301-patient PREOXI trial, found that non-invasive ventilation reduced the incidence of hypoxemia from 18.5 to 8.1% (absolute risk difference, − 9.4 percentage points; 95% CI, − 13.2 to − 5.6) and reduced the incidence of cardiac arrest from 1.1 to 0.2% (absolute difference, − 0.9 percentage points; 95% CI, − 1.8 to − 0.1). Further, the benefit of preoxygenation with non-invasive ventilation was more than three times as large for patients with obesity (9.0% versus 26.4%; absolute risk difference, 17.4 percentage points) as for those without obesity [23].

High-flow nasal oxygen has been proposed as an alternative to non-invasive ventilation for preoxygenation of critically ill adults. In addition to providing a high fraction of oxygen, high-flow nasal cannula provides flow-related positive end-expiratory pressure. However, multiple trials directly comparing preoxygenation with non-invasive ventilation versus high-flow nasal cannula have suggested a greater benefit from preoxygenation with non-invasive

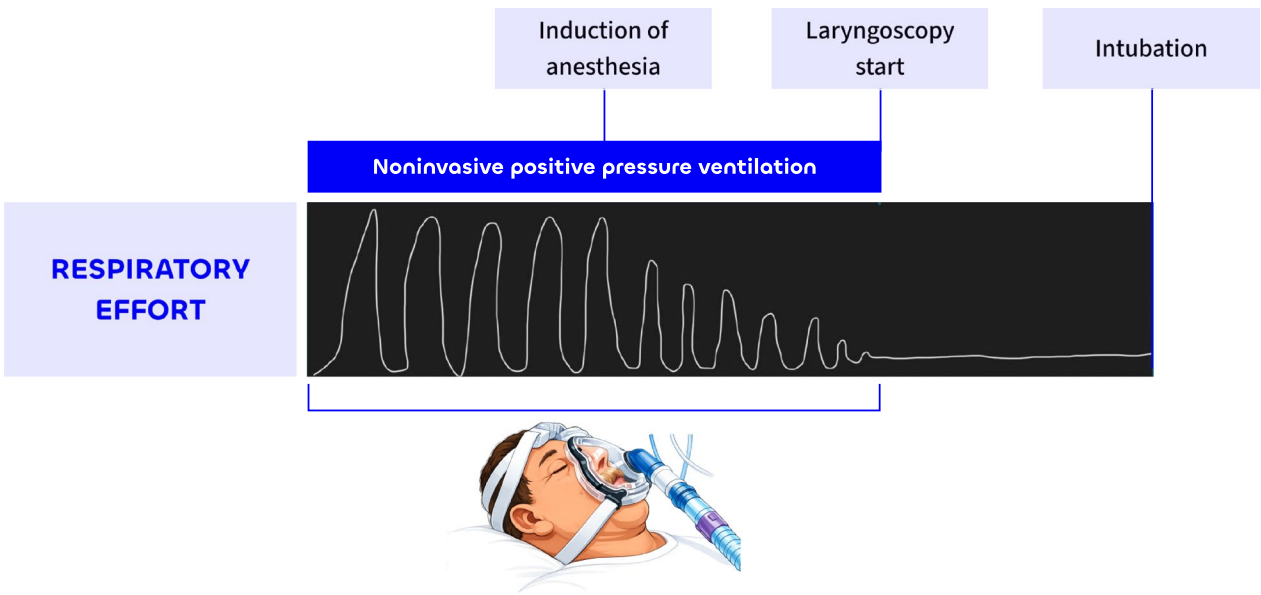

Fig. 1 Oxygenation and ventilation during intubation of the critically ill patients with obesity. Positive pressure ventilation delivered by non-invasive ventilation is associated with a decreased risk of hypoxemia during intubation in critically ill patients with obesity. Following administration of a sedative and neuromuscular blockade, there is a 30–90-s delay until patients are sufficiently relaxed to initiate laryngoscopy: administration of positive pressure during this phase reduces the risk of hypoxemia without appearing to increase the risk of pulmonary aspiration. This figure offers a conceptual summary. For more details, see the main text. FRC, functional residual capacity; NIV, non-invasive ventilation; PEEP, positive end-expiratory pressure; VL, videolaryngoscopy

ventilation, particularly among patients with pre-existing hypoxemia [26] and obesity [19].

Between induction and laryngoscopy

Following administration of a sedative and neuromuscular blockade, there is a 30 to 90-s delay until patients are sufficiently relaxed to initiate laryngoscopy. Whether the provision of positive-pressure ventilation during this period reduces hypoxemia or causes gastric insufflation and aspiration, compared to oxygen administration alone, has been a long-standing debate. The PreVent trial compared bag-mask ventilation versus no ventilation between induction and laryngoscopy among 401 adults undergoing tracheal intubation in ICUs in the United States [27]. It found that positive-pressure ventilation with a bag-mask device reduced hypoxemia (22.8% versus 10.9%; absolute difference, − 12.0 percentage points; 95% CI, − 19.3 to − 4.6) without any effect on aspiration. These results, together with the results of the trials of preoxygenation with non-invasive ventilation (which also provided positive-pressure ventilation between induction and laryngoscopy), suggest that the use of positive-pressure ventilation between induction and laryngoscopy is effective in preventing hypoxemia, without increasing the risk of aspiration in patients who are not at elevated aspiration risk (Fig. 1) [23–25]. While no trials have specifically evaluated this question among patients with obesity, physiology suggests that they may receive a greater than average benefit from positive-pressure ventilation between induction and laryngoscopy.

Apneic oxygenation

Once a laryngoscope is placed in the mouth, positive pressure ventilation using a face mask cannot be administered, but supplemental oxygen can be delivered by nasal cannula, an intervention referred to as *apneic oxygenation*. Trials evaluating the administration of apneic oxygenation during emergency tracheal intubation have failed to demonstrate a benefit in the prevention of hypoxemia when provided at 15 L per minute by standard nasal cannula [28, 29] or at 60 L per minute of 100% oxygen by high-flow nasal cannula [30–32]. While some meta-analyses have suggested a small benefit [33, 34], trials and meta-analyses limited to patients with obesity have not identified any benefit [35]. In patients with obesity, the combination of reduced FRC and increased oxygen consumption results in very limited oxygen reserve during apnea. For this reason, the physiological effectiveness of apneic oxygenation alone may be limited compared with strategies that increase lung volume, such as positive-pressure preoxygenation. Whether the addition of apneic oxygenation with high-flow nasal cannula to preoxygenation with non-invasive ventilation provides additional benefit is an area of active investigation [36].

In summary, existing evidence suggests that when performing emergency tracheal intubation of critically ill patients with obesity, efforts should focus on providing preoxygenation with non-invasive ventilation and applying positive-pressure ventilation between induction and laryngoscopy (unless a strong contraindication is present) [23, 37].

Are patients with obesity at risk of intubation failure?

Critically ill patients with obesity experience a 16% difficult intubation rate during direct laryngoscopy in the ICU, which is almost twice the rate of patients without obesity [2]. In this specific population of patients with obesity, some independent factors of difficult intubation were found, including: a Mallampati score of 3 or higher, reduced mobility of the cervical spine, obstructive sleep apnea syndrome, reduced mouth opening, coma, and hypoxemia before intubation. However, the degree of obesity does not seem to be associated with difficult intubation [38]. Similarly, a single-center retrospective analysis of electronic data from 67.000 adults undergoing elective non-cardiac surgery revealed that tracheal intubation became more difficult with increasing body mass index (BMI). However, the odds of a difficult intubation remained unchanged once BMI exceeded 30 kg/m^2 [38].

In a secondary analysis of the INTUBE study [4], obesity was associated with a higher likelihood of first-pass intubation failure. Meanwhile, critically ill patients with obesity exhibit a higher incidence of severe hypoxemia during intubation. Classic risk factors for failed first-attempt intubation were more prevalent among patients with obesity: These factors include a Mallampati score of III or IV, a short neck, and a reduced mouth opening.

More cardiac arrests related to intubation can be triggered by a combination of increased intubation failure and more hypoxemia. In a secondary analysis of a critically ill airway management database, overweight and obesity emerged as independent risk factors for cardiac arrest [39], likely due to a combination of more difficult anatomical and physiological airways [40].

Video laryngoscopy and adjuncts

In critically ill patients with obesity, failed or repeated intubation attempts are associated with severe hypoxemia, hemodynamic collapse, and cardiac arrest, making successful intubation on the first attempt a central determinant of safety [21, 41, 42]. Data are mixed as to whether obesity, on average, is associated with more difficult intubating conditions [43], but multiple large high-quality analyses have reported lower intubation success

and higher rates of peri-intubation complications for patients with obesity [2, 4]. Thus, first-attempt success is important for any critically ill patient and particularly important in the context of obesity. Successful intubation first requires obtaining a view of the larynx and then delivering the endotracheal tube. Video laryngoscopy (VL) and a stylet or a bougie (tracheal tube introducer) are key tools for these steps that together improve the likelihood of success.

VL has long been associated with higher success than direct laryngoscopy (DL) in observational studies [44, 45], but until recently there was a dearth of support from randomized trials, which were often single-center or had small sample sizes [46, 47]. Three recent large, pragmatic randomized trials now provide high-quality evidence that VL achieves higher first-attempt success across a wide range of operators and clinical environments, including patients with obesity. In a multicenter trial enrolling 1.417 intubations across 17 emergency departments and intensive care units, Prekker et al. found substantially higher success with VL compared with DL (85.1% vs 70.8%), although the magnitude of benefit decreased with increasing operator experience [22]. In a large cluster-randomized trial of 8.429 intubations in the operating theater, Ruetzler et al. demonstrated higher success with hyperangulated VL compared with DL (98.3% vs 92.4%), with similar effects observed among trainees and consultants [48]. Likewise, Kriege et al. reported higher success rates, a marked reduction in adverse events, and lower intubation failure rates with Macintosh VL, including among experienced operators [49]. In subgroup analyses, patients with obesity had findings similar to main analyses, i.e., higher rates of first-attempt success when VL was used [22, 48]. These recent large trials are consistent with intubation trials that have enrolled exclusively patients with obesity [50]. What remains unknown is whether Macintosh-style (standard geometry) VL compared with hyperangulated VL achieves higher success in general and in patients with obesity. Macintosh-style VL involves easier bougie and tube delivery, while hyperangulated VL more easily achieves laryngeal views, but requires slightly more difficult tube delivery around the sharp curve of the blade. Large upcoming trials should help answer this outstanding question (NCT07223762, NCT06322719).

VL assists in obtaining the laryngeal view. Tube delivery is the next step and is most often accomplished with the aid of a stylet or bougie [22, 51]. A stylet stiffens and shapes the tube, and a bougie is a thin rod that is advanced into the larynx and over which a tube is then advanced using the Seldinger technique. Potential advantages of the bougie include its narrower diameter, which allows greater maneuverability and visualization during tube delivery—but its use is often recommended for Macintosh-style VL. Observational and single-center randomized studies conducted in systems with established bougie use demonstrate improved success with bougie use [52, 53], but a large multicenter trial showed no difference in success between bougie and stylet use [20]. This trial, however, occurred in centers with limited bougie experience and most operators did not enroll more than 1 patient, and thus did not learn bougie use during the trial. When systems switch to routine bougie use, success has been observed to increase by 7–13% [54, 55]. Historical concerns about iatrogenic injury are not supported by modern data. Bougie use is safe with no observed differences in upper airway or tracheal injuries compared to use of a stylet when used by both novice [20] and experienced operators [53] and in a large systematic review [56]. Available evidence suggests that in critically ill patients with obesity, the combination of VL and a stylet (or a bougie when used by experienced operators) is more effective in maximizing first-attempt success than either device used alone [51].

From oxygen to perfusion: integrating hemodynamics into airway safety of the patient with obesity

In a study including 1400 patients with obesity, severe cardiovascular collapse (systolic arterial pressure < 65 mmHg recorded at least one time, 90 mm Hg lasting 30 min despite 500–1000 ml of crystalloids or colloids solutions loading and/or requiring introduction of vasoactive support), cardiac arrest or death was noted in 30% of the critically ill patients with obesity [2]. More recently, in a secondary analysis of the INTUBE study, there was no significant difference in the incidence of cardiovascular instability or cardiac arrest between patients with and without obesity [4]. These findings are reassuring in supporting that obesity per se does not appear to increase the incidence of cardiovascular collapse, despite concerns about increased incidence of right ventricular strain in patients with obesity [4].

A fluid bolus is commonly administered prior to tracheal intubation in an attempt to prevent cardiovascular collapse. Two randomized multicenter trials compared the administration of a 500 mL intravenous crystalloid bolus with no fluid bolus prior to tracheal intubation in critically ill adult patients [57, 58]. The first, the PrePARE study [57], was conducted in an unselected patient population, while the second, the PrePARE II study, involved patients who received positive pressure ventilation between induction and laryngoscopy [58]. This latter scenario is particularly relevant to patients with obesity, in whom positive-pressure ventilation is the recommended strategy. Both studies showed no reduction in the overall incidence of cardiovascular collapse following intubation

with the administration of a fluid bolus [57, 58]. Given these findings, the use of a fluid bolus in these settings may be considered on a case-by-case basis, potentially guided by an assessment of fluid responsiveness, if feasible. Two ongoing international trials, the FLUVA Trial (NCT05318066) and the PREVENTION Trial (NCT05014581), are currently investigating the effectiveness of the pre-emptive administration of norepinephrine in reducing the incidence of cardiovascular collapse in critically ill adults undergoing tracheal intubation. The results of these trials are expected to provide more definitive answers about what interventions prevent cardiovascular collapse.

Drugs used for induction of anesthesia for tracheal intubation can increase the risk of hemodynamic complications. A post-hoc analysis of the INTUBE study showed that the use of propofol (rather than etomidate, ketamine, or benzodiazepines) for the induction of anesthesia was the only modifiable independent predictor of cardiovascular collapse in these patients. Although the mean dose of propofol used in the INTUBE study was significantly less than standard anesthetic induction doses (1 mg/kg vs 2 mg/kg, respectively), the association of propofol with subsequent cardiovascular collapse appeared to be independent of the dose used [59]. Ketamine and etomidate, with their more stable hemodynamic profiles, have long been compared in terms of safety and efficacy in the general population of the critically ill. Concerns about increased long-term mortality associated with a single bolus of etomidate in critically ill patients have also been raised by recent meta-analyses and have been attributed to inhibition of 11-β-hydroxylase and the resulting adrenal suppression caused by the drug [60]. The recently published RSI trial showed that use of ketamine did not increase survival for critically ill adults undergoing emergency tracheal intubation, compared to etomidate [61]. Of note, the secondary outcome of cardiovascular collapse during intubation occurred in 22.1% of patients in the ketamine group and 17.0% in the etomidate group (absolute risk difference, 5.1 percentage points; 95% CI, 1.9–8.3%). In the subgroup of patients in the RSI trial with obesity, cardiovascular collapse occurred in 99 out of 396 (25.0%) patients in the ketamine group and in 72 out of 388 (18.6%) in the etomidate group (difference 6.4%, 95% CI 0.7–12.2, $P=0.03$), without observing a significant interaction between obesity and the induction drug (P value for interaction = 0.75, unpublished data from a not-planned sub-group analysis). Nevertheless, while awaiting definitive data on the most favourable induction agent from a hemodynamic standpoint, the decision to use ketamine or etomidate should be based on the clinical context, patient characteristics, availability and local practices. Weight-based dosing in patients with obesity is often challenging, as it may lead to overdosing with more pronounced hemodynamic effects, or underdosing, increasing the risk of awareness or suboptimal intubation conditions. Table 1 summarizes the dosing of commonly used induction agents in patients with obesity. However, in real-life emergency intubation scenarios, clinicians often adopt a pragmatic approach, rounding induction drug dosages based on measured or estimated total body weight. Finally, after post-intubation stabilization, mean airway pressure should be carefully titrated. Attention should be paid to PEEP, which may initially be set at low levels (around 5 cmH_2O) and then gradually increased as needed. In summary,

Table 1 Dosing of commonly used induction drugs in patients with obesity

Sedatives	
Ketamine	High lipophilicity with a large volume of distribution, rapid clearance, active metabolites [71] *Weight-based dosing: IBW or adjBW (especially with BMI ≥ 40 kg/m²)*
Etomidate	Large volume of distribution with relatively rapid liver metabolism but with poor correlation of clinical response with plasma concentration (concern of inadequate dosing and awareness) [71] *Weight-based dosing: TBW for BMI < 40 kg/m²; TBW or adjBW with BMI ≥ 40 kg/m²*
Muscle relaxants	
Rocuronium	Similar efficacy and intubation condition of IBW compared to TBW in rapid sequence induction [72] *Weight-based dosing: IBW*
Succinilcoline	Morbid obesity increases the amount of pseudocholinesterase and the volume of extracellular fluid. Dosing based on TBW provided better intubation conditions compared to lean and ideal body weights [73] *Weight-based dosing: TBW*

Please note that the evidence supporting the following suggestions is derived from single-center and/or observational studies, as well as data obtained in the operating room setting

AdjBW adjusted body weight, *IBW* ideal body weight, *TBW* total body weight

$IBW_{male} = 50 + 0.9 \times (height_{cm} - 152)$; $IBW_{female} = 45.5 + 0.9 \times (height_{cm} - 152)$

$AdjBW = IBW + 0.4 \times (TBW - IBW)$

bedside strategies that clinicians may consider to reduce peri-intubation cardiovascular collapse include careful assessment of intravascular volume status and its optimization before induction, early use of vasopressors (with a pre-emptive approach when appropriate), selection of either etomidate or ketamine based on local availability and preferences, and careful titration of positive pressure ventilation—particularly PEEP—once the patient is intubated [40].

Awake intubation of the ICU patient with obesity

Awake tracheal intubation (ATI) involves placement of a tracheal tube in a patient who is spontaneously ventilating with or without sedation. In peri-operative practice, ATI has been widely used, with the commonly reported success rates of > 99%, and a low incidence of severe adverse events [62, 63]. There are limited data describing outcomes with ATI in ICU settings. Both obesity and critical illness are independent risk factors for both anatomically and physiologically difficult airway management, and the combination of both, with or without further predictors of difficult airway management, may reasonably encourage clinicians to adopt ATI before clinical deterioration ensues. The intersection of multiple risk factors of potential difficulty and adverse outcomes means that ATI should be performed by clinicians experienced in the procedure, since hypoxemia, agitation, limited patient tolerance, and the urgency of intubation may result in a substantially more complex and higher-risk environment in the ICU than in the operating room. Having experienced nursing staff will help with preparation and safe performance. The Difficult Airway Society (DAS) recommends that ATI should ideally be performed in an operating room environment [64], however, transfer of the critically ill patient with obesity also carries risks, and thus, performing this procedure in the ICU may be required.

Ergonomic challenges may hamper the safe performance of practical procedures; therefore, ensuring there is adequate space for all equipment is imperative, and arranging the workspace to ensure adequate access to monitors (including waveform capnography), ventilators, infusion pumps, and a good view of the screen should be prioritized. Patients are ideally placed in the ramped

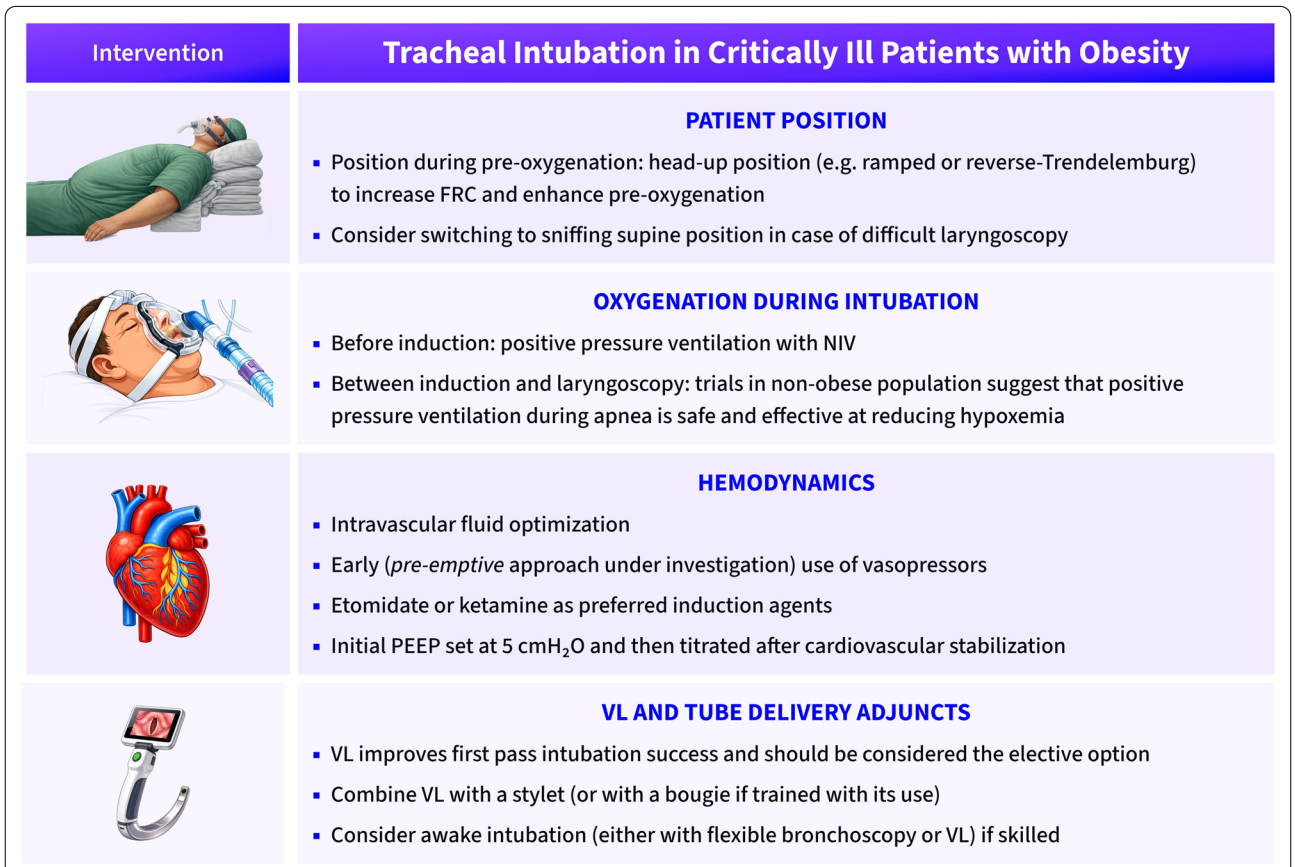
Intervention
Tracheal Intubation in Critically Ill Patients with Obesity
PATIENT POSITION
Position during pre-oxygenation: head-up position (e.g. ramped or reverse-Trendelemburg) to increase FRC and enhance pre-oxygenation
Consider switching to sniffing supine position in case of difficult laryngoscopy
OXYGENATION DURING INTUBATION
Before induction: positive pressure ventilation with NIV
Between induction and laryngoscopy: trials in non-obese population suggest that positive pressure ventilation during apnea is safe and effective at reducing hypoxemia
HEMODYNAMICS
Intravascular fluid optimization
Early (pre-emptive approach under investigation) use of vasopressors
Etomidate or ketamine as preferred induction agents
Initial PEEP set at 5 cmH2O and then titrated after cardiovascular stabilization
VL AND TUBE DELIVERY ADJUNCTS
VL improves first pass intubation success and should be considered the elective option
Combine VL with a stylet (or with a bougie if trained with its use)
Consider awake intubation (either with flexible bronchoscopy or VL) if skilled

Fig. 2 Peri-intubation interventions to reduce complications in critically ill patients with obesity. This figure offers a conceptual summary. For more details, see the main text

head-up position for ATI. Although reverse Trendelenburg positioning can also be used, this might compound hemodynamic instability.

Both flexible bronchoscopy and VL can be used for ATI, either alone or in combination. However, there is no strong data favouring one approach over the other; thus, clinicians should use what they are trained in and familiar with [65].

Administration of high-flow nasal oxygen at 100% FiO_2, with a flow rate of > 30 L/min will provide continuous oxygen delivery, may provide some positive end-expiratory pressure, and will allow for oxygenation should patients become apneic. Preoxygenation with a positive-pressure technique (e.g. non-invasive ventilation) before commencing ATI may also be beneficial and can be facilitated by light sedation (e.g. with ketamine), though the evidence in this particular setting (before ATI) is limited [37, 66].

Topical local anesthesia is a prerequisite for safe and effective ATI. If the nasal route is to be used, local anesthesia with a vasoconstrictor will improve visualization and reduce the risk of trauma and bleeding that could hamper ATI (e.g. lidocaine with phenylephrine). There are numerous techniques for topicalization [64], but local anesthesia dosing must be carefully considered and limited to 9 mg/kg of *lean* body weight to mitigate the risk of local anesthetic systemic toxicity, which is compounded by critical illness.

Minimal sedation to facilitate ATI in the critically ill patient with obesity may be beneficial. However, in this setting, this should be very cautiously administered given the high risk of hypoxemia, hypoventilation, airway obstruction, and hemodynamic instability. There is no strong evidence favouring any particular sedation strategy, but in this setting, propofol may be particularly hazardous [67].

Clinicians should be prepared to manage potential complications of ATI, such as hypoxemia, apnea, airway obstruction, hypotension, vomiting, aspiration, and airway failure. Around 1% of all ATIs are unsuccessful, and, therefore, preparing for a high-risk general anesthetic is generally advisable. Given the high-risk population, a plan for failure of tracheal intubation, supraglottic airway device ventilation and facemask ventilation should all be accounted for. Performing an airway ultrasound to localize and mark the cricothyroid membrane, should an emergency front-of-neck airway be required, might improve the likelihood of successful airway rescue, Fig. 2.

Towards safer airway management of the critically ill with obesity. Uncertainties and research agenda

More research is needed to improve the safety of airway management for critically ill patients with obesity. First, upcoming studies should focus on determining whether preventing hypotension during intubation with a vasopressor is associated with better outcomes, given the high rate of hemodynamic complications. The optimal vasopressor (ephedrine, phenylephrine, or norepinephrine), its dosage [68] according to real, adjusted, or predicted body weight, and the timing and dilution of its administration should also be assessed. The combination of fluid loading and vasopressors may reduce severe cardiovascular collapse associated with airway management [69].

Second, it is now well demonstrated that pressure support is the preferred method of preoxygenation. However, tolerance can sometimes be imperfect. A small dose of sedation, such as ketamine or propofol, could help physicians perform adequate preoxygenation without losing spontaneous ventilation [40]. However, more evidence is needed to assess the benefits and risks of this practice (sometimes referred to as "delayed sequence intubation").

Additionally, the required doses of hypnotics may be higher for patients with obesity, and titration may be more difficult for this population due to rapid release into body fat. Research is also needed to evaluate the combination of hypnotics used during intubation in the ICU according to real, adjusted, or predicted body weight. The classic Sellick maneuver remains controversial, particularly in critically ill patients with obesity, in whom intubation is often more challenging and may be further hindered if cricoid pressure is not promptly released when necessary. A trial could be planned to assess the efficacy and safety of the Sellick maneuver in critically ill patients with obesity at high risk of aspiration.

In the future, randomized controlled trials could assess the use of artificial intelligence to apply best practices for intubation in critically ill patients with obesity, aiming to reduce severe intubation-related complications such as hypoxemia and hypotension. Data showing fewer severe complications and cost-effectiveness are also lacking for the use of VL as the primary method of intubation [69].

A key limitation of this review is the extrapolation of evidence from the operating room setting to the critical care environment, due to the limited availability of data specifically derived from critically ill patients with obesity. This is particularly relevant for positioning strategies and awake intubation techniques. Until robust, population-specific data are available, any recommendations must be interpreted with caution, as current evidence may not accurately predict outcomes in critically ill patients with obesity.

Conclusions

Positive-pressure preoxygenation effectively increases functional residual capacity (FRC) and improves the safety of the intubation procedure [23]. A careful

assessment of the patient's hemodynamic status prior to intubation is essential and may be enhanced by the use of ultrasound [40]. Etomidate and ketamine are the most hemodynamically favorable induction agents; selection between them should be based on clinical judgment and local availability [61]. Clinicians should be aware of the critical transition phase from spontaneous to positive-pressure ventilation, which should be carefully titrated [70]. Videolaryngoscopy improves first-pass intubation success—an important goal in reducing peri-intubation complications, particularly hypoxemia [22, 45].

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VR, SJ and AD conceived the review. All authors participated in the manuscript draft preparation according to their expertise, provided suggestions and comments on the final draft. All authors approved the final manuscript version.

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Data availability
Not applicable. This article is a narrative review and does not report or analyze original data.

Declarations

Conflicts of interest
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